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FARMERS' BULLETIN No. 192.

BARNYARD MANURE.

[A Revision of Farmers' Bulletin No. 21.]

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BY

W. H. BEAL,
OF THE OFFICE OF EXPERIMENT STATIONS.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., January 25, 1904.

SIR: I have the honor to transmit herewith, and to recommend for publication, a Farmers' Bulletin on barnyard manure, prepared under my direction by W. H. Beal, of this Office. This bulletin is a revision of Farmers' Bulletin No. 21, based upon the large amount of data of investigations by the agricultural experiment stations and kindred institutions, which has accumulated since the original bulletin was prepared and published in 1894. In fact, the bulletin in its present form is in large part a summary of station work, and illustrates the very important advances which have been made in one of many useful lines of agricultural research pursued by these institutions. I feel sure that the importance of the manure produced by domestic animals in the economical management of our farms is not sufficiently appreciated, and hope that the presentation of the case in the light of the best practice, allied to the most thorough research, will serve to increase the attention paid to this essential element in successful farming.

Respectfully,

A. C. TRUE,
Director.

HON. JAMES WILSON,
Secretary of Agriculture.

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BARNYARD MANURE.[a]

MANURE AS A FARM RESOURCE.

A well-kept manure heap may be safely taken as one of the surest indications of thrift and success in farming. Neglect of this resource causes losses, which, though little appreciated, are vast in extent. Waste of manure is either so common as to breed indifference or so silent and hidden as to escape notice.

According to recent statistics there are in the United States, in round numbers, 19,500,000 horses, mules, etc., 61,000,000 cattle, 47,000,000 hogs, and 51,600,000 sheep. Experiments indicate that if these animals were kept in stalls or pens throughout the year and the manure carefully saved the approximate value of the fertilizing constituents of the manure produced by each horse or mule annually would be $27, by each head of cattle $20, by each hog $8, and by each sheep $2. The fertilizing value of the manure produced by the different classes of farm animals of the United States would, therefore, be for horses, mules, etc., $526,500,000; cattle, $1,220,000,000; hogs, $376,000,000; and sheep, $103,200,000, or a total of $2,225,700,000.

These estimates are based on the values usually assigned to phosphoric acid, potash, and nitrogen in commercial fertilizers, and are possibly somewhat too high from a practical standpoint. On the other hand, it must be borne in mind that no account is taken of the value of manure for improving the mechanical condition and drainage of soils, which, as the subsequent pages will show, is fully as important a consideration as its direct fertilizing value.

Discussing this subject from a more practical standpoint, Professor Roberts has suggested $250 as a conservative estimate of the value of the manure produced during seven winter months on a small farm carrying 4 horses, 20 cows, 50 sheep, and 10 hogs.

If we assume that one-third of the value of manure is annually lost by present methods of management, and this estimate is undoubtedly a conservative one, the total loss from this source in the United States,

[a] In this bulletin the term "barnyard manure" is used to mean the solid and liquid excrement of farm animals either alone or mixed with litter and more or less fermented.

as indicated by the first figures, would be about $708,466,000; or, using Roberts's figures, the annual loss for each farm would amount to $83.33.

It should be clearly understood that when the farmer sells meat, milk, grain, hay, fruits, vegetables, etc., from his farm, or neglects to save and use the manure produced, he removes from his soil a certain amount of potash, phosphoric acid, and nitrogen that must be restored sooner or later if productiveness is to be maintained.

The following table compiled by Armsby shows the amount and value of fertilizing constituents carried away from the soil in different products:

Manurial value of farm products.

	Pounds per ton.			Value per ton.				Manurial value of $10 worth.
	Nitrogen.	Phosphoric acid.	Potash.	Nitrogen.	Phosphoric acid.	Potash.	Total.	
Meadow hay	20.42	8.2	26.4	$3.47	$0.57	$1.06	$5.10	$5.10
Clover hay	40.16	11.2	36.6	6.83	.78	1.46	9.07	9.07
Potatoes	7.01	3.2	11.4	1.19	.22	.46	1.87	.12
Wheat bran	49.15	54.6	28.6	8.35	3.82	1.14	13.31	8.32
Linseed meal	105.12	32.2	24.8	17.87	2.25	.99	21.11	7.54
Cotton-seed meal	135.65	56.2	29.2	23.06	3.93	1.17	28.16	10.05
Wheat	37.53	15.8	10.6	6.38	1.11	.42	7.91	2.63
Oats	36.42	12.4	8.8	6.21	.87	.35	7.43	3.86
Corn	33.06	11.8	7.4	5.62	.83	.30	6.75	3.78
Barley	39.65	15.4	9.0	6.74	1.08	.36	8.18	3.03
Milk	10.20	3.4	3.0	1.73	.24	.12	2.09	.88
Cheese	90.60	23.0	5.0	15.40	1.61	.20	17.21	.69
Live cattle	53.20	37.2	3.4	9.04	2.60	.14	11.78	1.18

We learn from the above table [says Armsby] that the farmer who sells a ton of hay, for example, sells in this ton of hay fertilizing ingredients which, if purchased in the form of commercial fertilizers, would cost him about $5.10; that if he sells 2,000 pounds of wheat he sells an amount of nitrogen, phosphoric acid, and potash which it would cost him $7.91 to replace in his soil in the form of commercial fertilizers. Or, looking at it from a somewhat different standpoint, a farmer who sells, for example, $10 worth of wheat sells with it about $2.63 worth of the fertility of his soil. In other words, when he receives his $10 this amount does not represent the net receipts of the transaction, for he has parted with $2.63 worth of his capital, that is, of the stored-up fertility of his soil, and if he does not take this into the account he makes the same mistake a merchant would make should he estimate his profits by the amount of cash which he received and neglect to take account of stock.

If the farmer, instead of selling off his crops, feeds them to live stock on the farm as far as possible, a large proportion of this fertility, as has been shown above, is retained on the farm; and "if the business of stock feeding is carried to the point where feed is purchased in addition to that grown on the farm, a considerable addition may in this way be made to the fertility of the farm at an almost nominal cost, since it is assumed that feed will not be bought unless its feeding value will at least pay its cost." This commendable system of indirect purchase of fertilizers in feeding stuffs is practiced largely in England and other European countries, and accounts for no small share of the profits of stock raising in those countries.

But it is evident that these advantages will not be secured unless the manure produced is carefully saved and used.

The growing of more leguminous plants, such as beans, peas, clover, lupines, etc., as a means of increasing the fertility of the soil, is strongly recommended both from theoretical and practical considerations, but as a farmers' bulletin (No. 16) of the Department of Agriculture says:

> The leguminous crop is best utilized when it is fed out on the farm and the manure saved and applied to the soil. The greatest profit is thus secured, and nearly the same fertility is maintained as in green manuring. * * * The farmer should mend his system so that the barnyard manure will be as well cared for as any other farm product. Loss from surface washing, leaching, fermentation, and decay should be guarded against. Then the feeding of richer food will mean richer manure and better and cheaper crops.

It is hard to persuade the farmer to abandon time-honored practices and adopt methods with which he is unfamiliar. He also hesitates about incurring the necessary expense of building suitable receptacles for the storage of manure, frequently assuming that this is greater than it really is. As Roberts states, "The new idea that the manure should be as carefully preserved from unnecessary waste as any other product of the farm is hard to put in practice, after having for forty years stored the farmyard manure under the eaves upon the steep hillside which forms one border of the running brook."

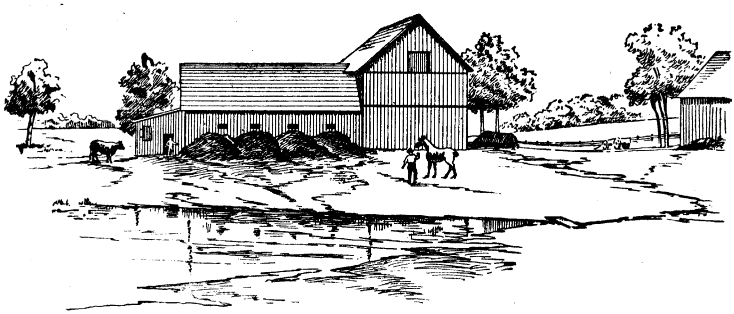

FIG. 1.—The waste of barnyard manure.

It is to be feared that the introduction of commercial fertilizers has not been without effect in increasing the apparent indifference with which this valuable farm resource is so often regarded. Too many farmers lose sight of the fact that, as a rule, commercial fertilizers should supplement and not entirely replace the manurial supplies of the farm.

AMOUNT, VALUE, AND COMPOSITION OF MANURE PRODUCED BY DIFFERENT ANIMALS.

It is of great importance to the farmer to know the amount and value of manure which will be produced in a given time by animals of different kinds, and various methods of calculating these approximately have

been proposed. Some authorities base their calculations upon the amount of straw used as litter, assuming that for 1 ton of straw used as bedding 4 tons of manure will be produced. Armsby shows, from carefully conducted experiments with horses, that where straw is used as economically as possible each horse will require 2,500 pounds of straw per year for bedding purposes. Using this as a basis, he calculates "that a ton of wheat straw, economically handled, may result in 6 tons of fresh manure," but under ordinary circumstances it will probably not result in more than 5 tons. "In stables where but one or two horses are kept, or where the manure is infrequently hauled away, the product might not greatly exceed 2½ tons when the time came to remove it."

Probably the most accurate method of estimating the manure product of farm animals which has been used is that adopted by Heiden and others, which bases all calculations upon the amount of food consumed and litter used.

The dried excrement of horses, cows and other neat cattle, and sheep is nearly one-half of the dry food consumed. According to Heiden, 100 pounds of dry matter in food consumed by horses yields 210 pounds of manure. To this should be added the weight of bedding (amounting to about 6½ pounds per day) in order to get the total product of manure. Making allowances for dung and urine dropped outside of the stable, Heiden calculates that a well-fed working horse will produce 50 pounds of manure per day, or 6½ tons per year, which can be saved. Boussingault's and Hofmeister's figures indicate this amount to be 5¼ to 5½ tons, while Armsby's put it at not more than 6 tons under most favorable conditions, and probably about 5 tons in general practice.

Cows and other neat cattle are stated by Heiden to produce for each 100 pounds of dry matter consumed in food 384 pounds of manure (dung and urine), to which must be added the amount of litter used, which, according to Heiden, should be about one-third of the dry matter fed. Calculating on this basis, a steer weighing 1,000 pounds and consuming 27 pounds of dry matter per day in food would produce about 113 pounds of manure per day or 20 tons per year. In experiments at the New Jersey Experiment Station with milch cows averaging 1,000 pounds in weight, the average daily production of manure (dung and urine), unmixed with litter, was only 70 pounds per cow, or at the rate of about 12¾ tons per year. With litter added this would probably be increased to 14 or 15 tons. In experiments at the Pennsylvania Station milch cows excreted on an average about 46 pounds of dung and 27 pounds of urine, or 73 pounds of total manure per day.

Sheep, according to Heiden, produce 183 pounds of manure for each 100 pounds of dry matter in food consumed. Using this basis of calculation, a 60-pound sheep consuming food containing 2 pounds of

dry matter and receiving three-fifths pound of bedding would produce about 4 pounds of manure per day, or three-fourths ton yearly.

From the most reliable data obtainable it is estimated that a hog produces from 6 to 10 pounds of manure per day, or from 1 to 1¾ tons per year.

According to Roberts, the quantity of manure produced by farm animals, as well as the quality, is influenced to a considerable extent by the character of the food. For example, the use of foods rich in nitrogenous matter (protein) increases the consumption of water and the excretion of urine, and may thus increase the quantity (bulk) of manure produced without improving its quality (see p. 16). The use of watery foods and high salting may produce the same result.

The following table, compiled from a bulletin of the New York Cornell Station, shows the amount and value of manure produced by the principal kinds of farm animals fed liberally and given sufficient bedding to keep them clean, calculated to a uniform basis of 1,000 pounds live weight:

Amount and value of manure produced per 1,000 pounds of live weight of different animals.

	Amount per day.	Value per day. [a]	Value per year. [a]
	Pounds.	*Cents.*	
Sheep	34.1	7.2	$26.09
Calves	67.8	6.7	24.45
Hogs	56.2	10.4	37.96
Cows	74.1	8.0	29.27
Horses	48.8	7.6	27.74

[a] Valuing nitrogen at 15 cents, phosphoric acid at 6 cents, and potash at 4½ cents per pound.

The fertilizing constituents and the value per ton of the manure obtained under the above conditions are shown in the following table, in which are inserted for comparison the results of analyses by Storer of manure of hens, which is representative of that of fowls in general:

Analyses and value per ton of manure of different animals.

	Water.	Nitrogen.	Phosphoric acid.	Potash.	Value per ton.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	
Sheep	59.52	0.768	0.391	0.591	$3.30
Calves	77.73	.497	.172	.532	2.18
Hogs	74.13	.840	.390	.320	3.29
Cows	75.25	.426	.290	.440	2.02
Horses	48.69	.490	.260	.480	2.21
Hens	56.00	0.80 to 2	0.50 to 2	0.80 to .90	7.07

The figures in these tables probably fairly represent the amount and actual fertilizing value of the carefully preserved manure (both solid and liquid) of well fed and cared for animals. In all cases the manure was protected from leaching, and in some cases it was treated with a small amount of gypsum as a preservative. They show that, as regards amount and value of manure produced for an equal amount

of live weight, hogs stand first, cows second, horses third, and sheep fourth; as regards value per ton of normal manure obtained (excluding that of hens), sheep and hogs stand first, horses second, and cows third (see p. 13). Hens have been shown by the Massachusetts Experiment Station to produce from one-fifth to one-fourth pound of manure per head daily, which, like all kinds of poultry manure, is much richer than that of other farm animals (see p. 14). "It will be noticed that the average amount of nitrogen recovered in all the manures is considerably more than that of the potash and about twice the amount of phosphoric acid."

In general practice the manure from the different kinds of animals is frequently collected in a common heap until needed. While it is difficult to state an average, ordinary mixed barnyard manure receiving reasonable care may be safely assumed to vary in composition within the following limits:

	Per cent.
Nitrogen varies from	0.4 to 0.8
Phosphoric acid varies from	0.2 to 0.5
Potash varies from	0.4 to 0.8
Water varies from	60 to 75

Snyder gives the following averages: Nitrogen, 0.5 per cent; phosphoric acid, 0.35 per cent; potash, 0.5 per cent. The actual averages obtained from a large number of analyses made by the Massachusetts Experiment Station of manure produced on different farms in that State are as follows: Nitrogen, 0.47 per cent; phosphoric acid, 0.33 per cent; potash, 0.49 per cent; water, 67.6 per cent. For practical purposes, therefore, it will be sufficiently accurate to estimate that well-kept manure will contain one-half per cent, or 10 pounds per ton, of nitrogen and potash, respectively, and one-third per cent, or $6\frac{2}{3}$ pounds per ton, of phosphoric acid.

COMPARATIVE VALUE OF SOLID AND LIQUID PARTS.

It is a fact often lost sight of in practice that the urine of animals is by far the most valuable part of the excreta. In experiments with milch cows at the Pennsylvania Experiment Station it was found that the urine contained more than one-half of the fertilizing matter of the food and nearly two-thirds of that of the total manure (dung and urine). The solid manure (dung) contains, principally, the fertilizing constituents of the food which have failed to be digested or absorbed into the animal system and are, therefore, chiefly in insoluble forms. The urine, on the other hand, contains those fertilizing constituents which have been digested and are largely soluble. The composition of the urine, like that of the dung, varies with the kind and age of the animal, but especially with the nature of food, water drunk, etc., as will be explained later. The composition of the urine of different kinds of farm animals has been found by analysis to be as shown on the next page.

Chemical composition of the urine of different animals.

	Water.	Nitrogen.	Phosphoric acid.	Alkalies.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Sheep	86.5	1.4	0.050	2.0
Swine	97.5	.3	.125	.2
Horses	89.0	1.2	....	1.5
Cows	92.0	.8	....	1.4

The urine of farm animals is practically free from phosphoric acid except in the case of sheep and swine, the urine of which contains minute traces of phosphoric acid, but is rich in nitrogen and the alkalies (including potash and soda). In the experiments at the Pennsylvania Station, referred to above, it was observed that the urine of milch cows contained about one-half of the nitrogen and three-fourths of the potash of the food consumed, but almost no phosphoric acid. The dung, on the other hand, contained about one-third of the nitrogen, one-sixth of the potash, and three-fourths of the phosphoric acid of the food. The remainder of the fertilizing constituents was found in the milk. In experiments with sheep at the Maine Experiment Station it was found that "the urine contained nearly half the potash of the total excreta and from half to three-fourths of the nitrogen, but no phosphoric acid, the latter being wholly in the solid excrement." Urine used alone is, therefore, an incomplete fertilizer, and should, as a rule, be supplemented by phosphates. It is best, however, to apply it along with the dung, which contains a considerable amount of phosphoric acid, but much less potash than the urine. These facts help to explain why leachings from mixed manure are often more valuable as a fertilizer than either dung or urine alone. The leachings contain, in addition to the constituents of the urine, the soluble matter of the dung, in which there is a considerable amount of phosphoric acid. Mixing the solid and liquid manure insures a better balanced fertilizer as regards potash, as well as phosphoric acid. Experiments made at the New Jersey Station show that the potash of cow dung varied from 0.13 to 0.27 per cent; in mixed dung and urine from 0.28 to 0.73 per cent, the percentage of phosphoric acid in the mixed manure being substantially the same as in the dung alone.

The comparative value of solid and liquid manure, as indicated by chemical composition, is shown in the following table:

Composition of solid and liquid excrement of farm animals.

	Water.		Nitrogen.		Phosphoric acid.		Alkalies (potash and soda).	
	Solid.	Liquid.	Solid.	Liquid.	Solid.	Liquid.	Solid.	Liquid.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Horses	76	89.0	0.50	1.20	0.35	Trace.	0.30	1.5
Cows	84	92.0	.30	.80	.25	Trace.	.10	1.4
Swine	80	97.5	.60	.30	.45	0.125	.50	.2
Sheep	58	86.5	.75	1.40	.60	.050	.30	2.0

The urine is seen to be much richer than the solid dung in every case except that of hogs, in which the high percentage of water (97.5) causes the percentages of the other constituents to fall below those of the same constituents in the solid dung.

The fact that the urine of all farm animals (including hogs) is much richer than the solid excrement is strikingly brought out in the following table, which shows the composition of the dung and urine after the water has been completely removed:

Composition of dry matter of solid and liquid manure.

	Nitrogen.		Phosphoric acid.		Alkalies (potash and soda).	
	Solid.	Liquid.	Solid.	Liquid.	Solid.	Liquid.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Horses	2.08	10.9	1.45	Trace.	1.25	13.6
Cows	1.87	10.0	1.56	Trace.	.62	17.5
Hogs	3.00	12.0	2.25	5.00	2.50	8.0
Sheep	1.78	10.4	1.42	.37	.71	14.9

The distribution of the manurial constituents in the urine and dung depends largely on the nature of the food. On this point Warington says:

> If the food is nitrogenous and easily digested the nitrogen in the urine will greatly preponderate; if, on the other hand, the food is imperfectly digested the nitrogen in the solid excrement may form the larger quantity. When poor hay is given to horses the nitrogen in the solid excrement will exceed that contained in the urine. On the other hand, corn, [oil] cake, and roots yield a large excess of nitrogen in the urine.

In general, therefore, it may be said that: (1) Of the nitrogen, phosphoric acid, and potash supplied in the food, comparatively small amounts are assimilated and retained in the animal body, the relation between the amounts of these substances excreted in the urine and the solid excrement depending largely upon the nature of the food. (2) The urine is much richer in nitrogen than the solid dung, usually containing one-half or more of the total amount excreted; it also contains a large proportion of the potash, but is poor in phosphoric acid, which remains almost entirely in the solid excrement. The best results may therefore be expected from applying the mixed solid and liquid excrement.

The fertilizing value of barnyard manure, as of any material, is, however, not determined exclusively by the total amounts of nitrogen, phosphoric acid, and potash it contains, but depends to a very large extent upon the ease with which these constituents are utilized by the plant, i. e., upon their availability. Voorhees, in a series of experiments at the New Jersey Station, found that, as compared with the nitrogen of nitrate of soda taken as 100, the availability of the nitrogen of fresh cow dung was 36.3; leached dung, 36.6; fresh mixture of dung and urine, 70.5; leached mixture of dung and urine, 48.1. The corresponding figures for sulphate of ammonia were 94.8; for dried

blood, 94.7. It was found in experiments at the Canada Experimental Farms that about 80 per cent of the phosphoric acid of fresh mixed horse and cow manure (with litter), 80 per cent of that of protected fermented manure of the same kind, and 40 per cent of that of exposed fermented manure was available, i. e., soluble in a weak organic acid (1 per cent citric acid). About 90 per cent of the potash of the fresh manure was available, and this proportion was practically unaffected by fermentation. These figures indicate that, as regards availability of its constituents, barnyard manure when properly handled and protected compares very favorably with the better class of commercial fertilizers.

The figures given in the preceding pages have only approximate and comparative value. They do not admit of too strict an application in practice, because barnyard manure, as can be readily understood, is a very variable substance. Its composition and value depend on a variety of conditions, the more important of which are (1) age and kind of animal, (2) quantity and quality of food, (3) proportion and nature of litter used, and (4) method of management of the manure and the length of time it is stored. Each of these factors will be discussed in detail.

INFLUENCE OF AGE AND KIND OF ANIMAL.

The proportions of the potash, phosphoric acid, and nitrogen of the food recovered in the manure vary considerably with the age and kind of animal. Full-grown animals, neither gaining nor losing weight, excrete practically all of the fertilizing constituents consumed in the food. Rapidly growing animals may excrete as little as 50 per cent of the fertilizing constituents of the food; while milch cows excrete from 65 to 85 per cent; and fattening or working animals from 90 to 95 per cent. The Mississippi Experiment Station found that young fattening steers excreted on an average 84 per cent of the nitrogen, 92 per cent of the potash, and 86 per cent of the phosphoric acid of the food consumed. The Pennsylvania Station reports experiments in which milch cows excreted 83 per cent of the nitrogen, 92 per cent of the potash, and 75 per cent of the phosphoric acid of their food.

It has been shown on previous pages that both the amount and the value of manure vary to a considerable extent with the kind of animal producing it, the animals producing the smaller amounts as a rule yielding the richer manure. Thus, sheep which produce the smallest amount of manure per 1,000 pounds of live weight rank with hogs in yielding that of greatest value per ton, and cows which stand first as regards production rank lowest as regards quality. Hogs, however, stand in the front rank as regards both amount and quality of manure produced. These differences are explained to a large extent by the dissimilar feeding habits of the different kinds of animals, but especi-

ally by variations in the water content of the manures. The general characteristics of the manure produced by different kinds of animals are as follows:

Sheep manure contains a small amount of water and is, weight for weight, the richest manure produced by any of the common farm animals. It is what is called a hot manure, fermenting rapidly with the development of heat. Like horse manure, it is especially likely to lose ammonia.

Horse manure is very dry, and is, therefore, difficult to thoroughly mix with litter. It is a hot manure, undergoing fermentation rapidly and generating a high heat on account of its loose texture. It is likely to lose ammonia even more rapidly than sheep manure, and requires careful management from the moment it is voided. The composition of horse manure is more uniform than that of any other farm animal, chiefly because the food of horses is more uniform. The urine is especially rich.

Hog manure is very variable in composition, owing to the variable nature of the food supplied to this animal, but is generally rich, although containing a high percentage of water. It generates little heat in decomposing.

The manure of neat cattle, like that of hogs and for the same reason, is variable in character, but is generally poorer than that of other farm animals on account of its large percentage of water. It decomposes slowly and develops little heat.

Poultry manure is very rich in all the fertilizing elements, but especially so in nitrogen, owing to the fact that the urinary secretions, which contain large amounts of nitrogen as well as potash in readily available form, are voided with the solid excrement. It quickly loses nitrogen, however, by fermentation, if not properly mixed with absorbents or preservatives. In no case should alkaline substances like lime, wood ashes, etc., be mixed with poultry manure.

INFLUENCE OF QUALITY AND QUANTITY OF FOOD.

In a given class of animals the value of the manure is determined more by the nature of the food than by any other factor. The quantities of nitrogen, phosphoric acid, and potash in manure stand in direct relation to the quantities of the same ingredients in the food. The crop-producing power of the manure will be largely determined by the nature of the food supplied to the animals producing it. The following table, adapted from a bulletin of the New York Cornell Station, shows the wide variation in manurial value of some of the more common feeding stuffs. (See also table, p. 6.)

Fertilizing value of feeding stuffs.

	Value of nitrogen in 1 ton.	Value of phosphoric acid in 1 ton.	Value of potash in 1 ton.	Total fertilizing value per ton.
Corn meal	$4.53	$0.83	$0.31	$5.66
Corn silage	.78	.14	.32	1.24
Crimson clover (green)	1.29	.16	.44	1.89
Crimson clover hay	6.63	.82	2.26	9.71
Red clover hay	5.70	.54	1.31	7.55
Gluten meal	15.09	.39	.05	15.53
Cotton-seed meal	20.85	3.66	1.65	26.16
Linseed meal	16.08	2.28	.99	19.36
Meat scrap	29.01	6.01	.67	35.69
Wheat	7.08	.96	.45	8.49
Oats	5.36	.90	.45	6.70
Skim milk	1.74	.26	1.08	2.11
Timothy hay	3.00	.43	1.17	4.60
Wheat bran	7.56	3.40	1.34	12.30
Wheat straw	.81	.30	1.02	2.18
Turnips	.48	.14	.34	.96

As already explained, from 50 to 95 per cent of the fertilizing constituents of food is recovered in the manure, depending upon the kind of animal fed (see p. 13).

In order to find from this table the amount of nitrogen, phosphoric acid, and potash which may be expected in manure, it is necessary simply to subtract from the amount of these constituents contained in the food the amount retained in the animal body. It can be readily seen that as regards the value of the manure produced the concentrated feeding stuffs, such as meat scrap, cotton-seed meal, linseed meal, and wheat bran, stand first; the leguminous plants, such as red and crimson clover, etc., second; the cereals (wheat, oats, corn, etc.), third, and root crops last. Thus with full-grown animals neither gaining nor losing weight practically all of the fertilizing constituents of the food are obtained in the manure, and each ton of wheat bran, for example, fed would theoretically yield manure having a fertilizing value of $12.30, each ton of clover hay $7.50, each ton of oats $6.70, and each ton of turnips 96 cents. With growing animals, milch cows, etc., only about 75 per cent of these amounts, or $9.20, $5.60, $5, and 72 cents, respectively, would be obtainable in the manure. Finally, with working and fattening animals, which excrete about 90 per cent of the fertilizing constituents of their food, the corresponding amounts would be $11, $6.75, $6, and 86 cents, respectively. It must not be assumed, however, that these values can be fully realized in ordinary practice. The unavoidable losses which occur in the handling of manure (see p. 16) render this impossible.

As the table shows, the amount of nitrogen present in foods is the most important element in determining the value of the manure, since it is the most costly fertilizing constituent and is present in much larger proportion, as a rule, than phosphoric acid and potash. The inorganic substances of foods (potash, phosphoric acid, lime, etc.) pass very largely into the manure; consequently the manure is proportion-

ately richer in these constituents than the food. The case is somewhat different with the nitrogenous substances, which are partly used in the production of meat, tendon, wool, milk, etc., thus leaving the manure in many cases poorer in nitrogen than the food consumed. Those, however, which are not so used undergo modifications in the process of digestion which render their nitrogen more available to plants.

As the New York Cornell Station has shown, increasing the amount of nitrogenous matter in the food increases the secretion of urine, thus necessitating the use of more litter and by this means increasing the bulk and reducing the quality of the manure produced. The use of nitrogenous foods thus brings about the same result as the use of watery foods or high salting. High feeding results in less complete digestion of the food and thus produces richer manure than low feeding. According to Roberts, animals kept in cold quarters digest their food more closely and hence may produce poorer manure than those more warmly housed. However, they also drink less water and consequently are likely to produce drier and more concentrated manure.

INFLUENCE OF THE NATURE AND PROPORTION OF LITTER.

Litter is used to furnish a clean and healthful bed for animals, to absorb and retain liquid excrement, to extend manure and render it easier to handle, to increase the physical and in some cases the chemical action of manure, and to check and control decomposition. The materials generally used are not, as a rule, rich in fertilizing constituents, as the following table of composition given by Warington will show:

Fertilizing constituents in one ton of litter.

	Nitrogen.	Phosphoric acid.	Potash.
	Pounds.	*Pounds.*	*Pounds.*
Dead leaves	16	6	6
Straw	8 to 12	4 to 6	12 to 32
Peat moss	16	Trace.	Trace.
Sawdust	4 to 14	6	14
Spent tan	10 to 20	....	....
Peat	20 to 40	....	....

The use of litter therefore tends to dilute manure rather than improve its chemical composition, but it absorbs and holds the valuable liquid parts and reduces the loss due to fermentation.

MANAGEMENT OF MANURE.

We have seen that barnyard manure is a material which rapidly undergoes change. Where it is practicable to haul the manure from the stalls and pen and spread it on the field at short intervals the losses of valuable constituents need not be very great, but when (as in winter) the manure must be stored for some time the difficulties of preservation become greatly increased.

Under these conditions, deterioration of manure results from two chief causes: (1) Fermentation, whereby a certain amount of the nitrogen is lost, and (2) weathering or leaching, which involves a loss of the soluble fertilizing constituents, including potash and phosphoric acid as well as nitrogen.

FERMENTATION OF MANURE.

The fermentation of manure is due to the action of minute microscopic organisms which belong to two great classes: (1) Those which require an abundant supply of air (oxygen) and which die when deprived of oxygen—known as aerobic ferments; and (2) those which grow without oxygen and die when exposed to it—known as anaerobic ferments.

The decomposition observed in the manure heap is due as a rule to the combined action of these two classes of ferments. On the outer surface of the heap, where the air circulates freely, the first class (aerobic) is active, while in the interior of the heap, where the supply of air is limited, the fermentation is due to the anaerobic ferments. The latter soon run their course and cease to exist. Their function seems to be principally to break up the more complex substances of the manure and prepare them for the further action of the aerobic ferments, which finally convert them into simpler compounds, such as water, carbon dioxid, and marsh gas.

Where the manure is compacted (as in deep stalls, for instance) the carbon dioxid formed by fermentation soon permeates the mass so completely as to entirely exclude the air, thus arresting fermentation. In loose heaps into which air is freely admitted fermentation of the aerobic form may go on indefinitely.

The fermentations of manure are very complex and vary according to circumstances. The principal conditions affecting these processes are (1) temperature, (2) supply of air as determined by compactness of heap, (3) moisture, (4) the composition of the manure, and (5) the nature of preservatives added.

The higher the temperature the more rapidly will manure decay. In aerobic fermentation of manure the temperature may rise to 122° to 140°, or even 158° F. On the other hand, in the interior of the heap, where anaerobic fermentation is in progress, the temperature rarely rises above 95° F. Experiments have indicated that 131° F. is the most favorable temperature for manure fermentations.

As already explained, the supply of air determines whether the slow-acting anaerobic ferment or the more vigorous aerobic ferment predominates. The careful regulation of the two kinds of fermentation is necessary to the successful rotting of manure. If the heap is too loosely built the decomposition is too rapid. The materials useful for

the formation of humus in the soil are destroyed, and the nitrogen, especially that of the urine, escapes into the air, partly as ammonia, partly as free nitrogen. On the other hand, if the manure is too firmly packed the decomposition may be too slow and the manure will not become sufficiently disintegrated to produce the best effect in the soil.

It has been found that barnyard manure contains in large numbers microscopic organisms which cause denitrification—that is, they decompose nitrates and set the nitrogen free in the gaseous form. For this reason nitrates are not found in fermenting manure and should not be mixed with it. It has even been asserted that the application of manure may result in considerable losses of nitrogen from the nitrates of the soil from this cause, but recent experiments make it clear that such losses occur, if at all, only in case of excessive applications of manure, and that on the other hand ordinary applications of manure favor nitrification, or the formation of nitrates, in the soil.

A powerful means of controlling fermentation is the supply of moisture. The addition of water lowers the temperature and thus retards fermentation. By filling up the pores of the mass and excluding the air it checks aerobic fermentation when this becomes too active. French authorities maintain that the principal precautions necessary to prevent losses of ammonia consist simply in regularly and properly watering the manure with the leachings. In case of drought, if the leachings are insufficient, the lack should be made up with water.

The need of keeping manure moist is especially marked in case of horse manure, which is naturally dry and decomposes with great rapidity. The same is true in a less degree of sheep manure. The common and harmful "fire-fanging" is the result of an insufficient supply of water and may be readily checked by sprinkling. The sprinkling, however, should be regularly done and the heap kept in a constant state of moisture, otherwise the alternate wetting and drying will result in a loss of ammonia. Preservation of manure in this manner is generally practiced in Europe, and the product obtained is highly esteemed as a fertilizer. It is "very dark colored, or even black, and acquires a highly offensive odor, while the straw in it loses its consistency and becomes soft and incoherent." This black substance is held by certain French agriculturists to possess special value as a plant food. A method employed in the preparation of this well-rotted manure in France is as follows: The manure is placed on slightly inclined plats of packed earth or cement, so arranged that the leachings drain out into a pit, from which they are pumped up and distributed over the manure heap. It is usual to provide two manure plats, so arranged that when one is full (when the manure is 8 to 10 feet high) it may be allowed to ferment undisturbed while the other is used. The manure is carried from the stables to the top of the manure heap in wheelbarrows over an inclined plane of boards. Care is also

taken to smooth down the sides of the heap, to prevent the too free access of air and the loss of leachings. The system here described is illustrated in fig. 2.

It has been questioned whether the construction of expensive cisterns for collecting the manure leachings repays the cost, but it is obviously desirable from what has been said regarding the value of the liquid manure and the desirability of promoting regular and uniform fermentation of the manure that the leachings should be saved and added to the manure heap by some means. Stored separately, the liquid part rapidly deteriorates and the solid part, from lack of moisture, is liable to undergo "fire-fanging" or harmful fermentation.

The nature and extent of fermentation in manure also depends to some extent on the composition of the manure, more particularly upon the amount of nitrogen in a soluble form which it contains. The greater the amount of soluble nitrogen the more rapid the fermentation. Urine, as we have already seen, is rich in soluble nitrogenous compounds, and this explains why it decomposes so rapidly.

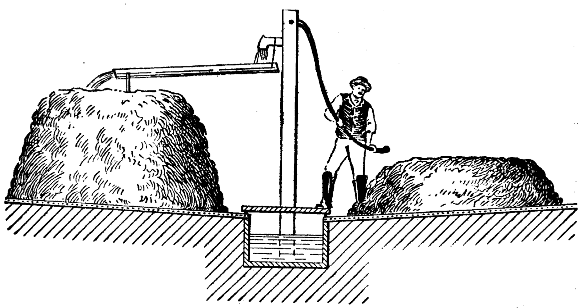

FIG. 2.—The French method of keeping manure.

By fermentation manure decreases rapidly in bulk. The substances of which it is composed are converted largely into water and gases, principally carbon dioxid, and where fermentation is not properly controlled, nitrogen may escape either in the free gaseous state or as ammonia. The coarse materials of the manure are gradually decomposed and are dissolved to a considerable extent in the black liquid which oozes out of the manure heap. As already shown (p. 13), the mineral matter (phosphates, potash, etc.) is also rendered more soluble. When properly controlled, therefore, fermentation is a valuable means of increasing the availability of the fertilizing constituents of manure, although it decreases the bulk; but when not properly controlled it seriously reduces the value of the manure.

LEACHING OF MANURE.

Leaching is the second cause of deterioration of manure. When manure is exposed to the action of the elements and the leachings

allowed to drain away it rapidly decreases in value. Both the organic and the mineral constituents originally present, or which have been made soluble by fermentation, are carried off and lost. Experiments at the New York Cornell Experiment Station indicated "that horse manure thrown in a loose pile and subjected to the action of the elements will lose nearly one-half of its valuable fertilizing constituents in the course of six months; and that mixed horse and cow manure in a compact mass and so placed that all water falling upon it quickly runs through and off is subjected to a considerable, though not so great, loss."

The Kansas Station concludes from similar observations "that farmyard manure must be hauled to the field in spring, otherwise the loss of manure is sure to be very great, the waste in six months amounting to fully one-half of the gross manure and nearly 40 per cent of the nitrogen that it contained."

In more recent experiments at the New Jersey stations solid cow dung exposed to ordinary leaching for one hundred and nine days lost 37.6 per cent of its nitrogen, 51.9 per cent of its phosphoric acid, and 47.1 per cent of its potash. Mixed dung and urine lost during the same time 51 per cent of its nitrogen, 51.1 per cent of its phosphoric acid, and 61.1 per cent of its potash. In brief, according to Voorhees, "more than one-half of the constituents in the total animal manure product of the cow may be lost by an exposure of less than four months."

In experiments at the Canada Experimental Farms a 4-ton lot of horse manure (with litter) kept in an open bin lost one-third of its nitrogen, one-sixth of its phosphoric acid, and a little more than one-third of its potash in one year. A similar lot of manure kept in a closed shed lost only one-fifth of its nitrogen and practically no phosphoric acid and potash.

In experiments by Voelcker in England, mixed manure stored in a heap under cover lost 14 per cent of its nitrogen in twelve months; exposed in a heap, 30 per cent; and exposed in thin layers, 64 per cent.

Of course the losses recorded in these experiments are not entirely due to leaching, but in case of nitrogen are to be attributed largely to fermentation, which sets some of this constituent free. Fermentation also increases the solubility of all of the constituents, and thus increases the amounts removed by leaching.

Field experiments on various crops have shown that the margin of profit from badly leached open-yard manure is at best extremely small.

PRESERVATION OF MANURE.

Having now briefly discussed the nature and extent of the changes which manure is likely to undergo when stored in heaps, let us inquire

into the best means of preventing loss of fertilizing value during these changes. It is a well-known fact that certain of the organisms which cause decomposition of manure are voided with the dung and commence their activity at once. In case of horses and sheep these organisms cause a considerable loss of ammonia in a comparatively short time. It is necessary, therefore, to adopt prompt measures in order to reduce loss from this source to a minimum. The means which are available for this purpose are the use of absorbents (litter) and preservatives. The litter takes up the liquid manure, thus preserving it to some extent from decomposition, and also absorbs to a considerable extent the ammonia produced by fermentation and prevents its escape into the air.

The relative absorptive power of various materials commonly used as absorbents in stables is shown in the following table:

Absorptive power of different kinds of litter.

	Water retained by 100 pounds of material after 24 hours.	Ammonia absorbed by 100 pounds of dry matter in different materials.
	Pounds.	*Pounds.*
Wheat straw	220	0.170
Partially decomposed oak leaves	162	....
Peat	600	1.103
Sawdust	435	.046
Spent tan	450	....
Air-dried humus soil	50	.660
Peat moss	1,300	.863

The figures in this table indicate that peat and peat moss are the best absorbents. It has already been shown (p. 16) that they also furnish the largest amounts of fertilizing constituents. Peaty soil is also an effective absorbent, and the use of a mixture of peaty earth with straw as litter has been strongly recommended. Sawdust, on the other hand, has little to recommend it, except its availability and cheapness. It is a poor absorbent, contains little fertilizing matter, and decomposes very slowly in the manure heap and in the soil. An addition of from 35 to 40 pounds of loam per head daily has been found advantageous, and where straw is scarce it has been replaced to the extent of one-fourth or one-third by earth. The amount of litter required for any given animal depends largely upon the character of the food. Watery foods and those containing a large amount of nitrogen increase the secretion of urine, and so increase the amount of litter necessary to absorb the liquid and keep the animal clean. A safe general rule is that the litter should amount to at least one-third of the dry matter of the food consumed. The following amounts per day for different animals are recommended: Sheep, three-fifths pound of litter; cattle, 9 pounds; and horses, 6½ pounds.

It is not advisable as a rule to use an excess of litter beyond that required to keep the animal clean and absorb the liquid excrement, since the materials available for bedding are as a rule poor in fertilizing constituents, and so extend and dilute the manure unnecessarily.

A small amount of gypsum (land plaster) sprinkled on the moist dung or urine is commonly used as a means of fixing the ammonia. Kainit and acid phosphate (superphosphate) have also been recommended as preservatives of manure, but recent experiments indicate that none of these substances is of much value for preventing loss of nitrogen, which is the main object of the use of preservatives. In fact, the investigators who have given the most attention to the subject of the preservation of manure are generally disposed to attach much more importance to the proper use of absorbents and to keeping the manure heap compact and uniformly moist than to the use of preservatives. If kainit and acid phosphate are used they will increase the value of the manure by adding potash and phosphoric acid. If applied in the stall they should be covered with litter so that they do not come in contact with the feet of the animals.

In cases where different kinds of animals are kept, one of the most effective means of securing moderate and uniform fermentation of the manure heap is to see that the moist "cold" cow and pig manure is intimately mixed with the dry "hot" horse and sheep dung. The former makes the heap more moist and checks the too rapid fermentation and "fire-fanging" of the latter.

It thus appears that in order to reduce the loss to a minimum, manure heaps should be made compact and kept uniformly moist. Under cover the last result is secured by collecting the liquid manure and at frequent intervals sprinkling it over the heap, or when the supply of this is deficient, by sprinkling with water. Where the manure heap is exposed to the rain in pits from which there is no drainage it probably does not require so much attention, but still care must be taken to prevent loss by alternate leaching when heavy rainfalls occur and drying out in time of drought.

Regarding the management of manure, Professor Frear. of the Pennsylvania Experiment Station, says:

> To secure such kind and degree of rotting as shall make the manure easily handled and put it into the condition best suited to the crops it is to fertilize, both extremes of moistness and cold, and of exposure and heat, are to be avoided.
>
> It is a much-discussed question whether this mean condition is best obtained in practice by the preservation of the manure in dished yards, subject to more or less exposure to wind and sun, to full exposure to rain, but to more loosely leaching, or under covered sheds where it is protected from sun and rain, and largely from wind. In both cases it is supposed to be compacted fully as the heaps are forming.

Storer expresses a doubt whether sheds built to shelter manure have ever paid their cost. On the other hand, Professor Roberts, of the New York Cornell Station, recommends the construction of sheds

or covered yards for the protection of the manure. The use of completely covered barnyards for protecting manure has in recent years met with much favor in certain parts of the country. The manure from the horse and cattle stables and the sheep and calf pens is spread out evenly over these yards, covered with coarse litter, and the whole kept firmly packed by allowing animals to run over it, thus preventing injurious fermentation. The construction of a cheap and durable covered yard, illustrated in fig. 3, is thus described by Roberts:

Long posts or poles, 8 inches in diameter at the butt, are set in the ground 2 feet deep and 6 feet apart. Upon these are spiked 2 by 4 scantling, about 4 feet apart, for nailing girts, and a plate 2 by 6 is nailed on top of the posts which have been previously sawed off to a line after the girts have been spiked to them. Round poles flattened at the ends, or 2 by 6 joists doubled, spiked to the heads of the posts, will tie the building together. Ten feet will be quite high enough for the story; and one story will suffice if no straw is to be stored above except that which is placed there to exclude the cold. A few poles or old rails laid on these cross-ties which bind the building together will suffice to sustain the weight of the straw, while the straw will exclude the cold, and absorb the moisture far better than an expensive matched ceiling.

On the inside of the posts which have been set in the ground flattened poles, rails, or slabs, or cheap boards may be nailed horizontally, and the space between the outside vertical boarding and the inside horizontal boarding may be filled with straw. This kind of a wall is far drier and more comfortable for the animals than one made of costly stone or brick.

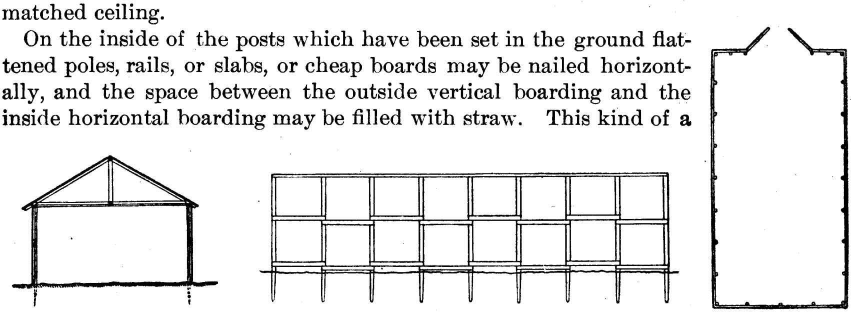

FIG. 3.—Plans for a cheap covered barnyard.

If it is desired to have a place to store straw, the building should be higher, the joists stronger and more numerous than in the one-story building, and they will all have to be supported by a timber supported by posts placed under their centers. The roofs should be steep, and can be made of any material which will shed water. When the posts which have been set in the ground have rotted off, or are much decayed, they may be sawed off even with the ground and supported by placing underneath each one of them a large flat stone. Whenever the building is treated in that way it will be necessary to brace it thoroughly. It might be well in a windy country to brace so wide a building at the start.

Such a building will be inexpensive and reasonably durable. It will serve as a place for depositing manure when needed; it will shelter the animals while they are being watered and the stables are being cleaned and aired, and give facilities for preventing loss of valuable fertilizing material either by leaching or firing.

Many stables are so situated that by adding a cheap lean-to, as shown in fig. 4, "a receptacle for caring for the manure is easily provided. The outside boarding of the lean-to should be, for a part of the way at least, put on horizontally and hung in the form of flat doors, so that

the manure can be easily loaded on a wagon standing on the outside of the building."

The unsatisfactory results attending the use of manure sheds and covered yards have probably been due to the fact that these structures have generally been loosely constructed, allowing the free circulation of air, which has dried out the manure. We have already seen the losses caused by dry fermentation. On this account barn cellars, so common in New England, possess decided advantages as receptacles for manure. The common practice of allowing swine to "work over" the manure in these cellars is a wise one, since it mixes the manure and keeps it well packed and moist. In fact, if these cellars are provided with impervious bottoms to hold the liquid manure, this system of storing manure is very efficient.

In the method practiced in France the manure heap is under cover and well compacted. Loam, peaty earth, or similar materials are added to insure moderate fermentation. The impervious floors on which the heap is placed, as explained on page 18, are so arranged that the leachings may be collected and returned to the heap, thus keeping it moderately moist. To prevent mixing fresh manure with old, two floors are provided, so that the manure on one may ferment undisturbed while the other is used.

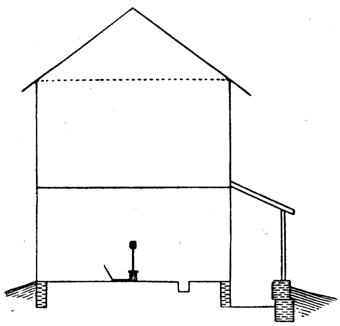

FIG. 4.—A cheap shelter for manure.

The method in which the manure is carried regularly from the stable and placed in shallow pits with impervious bottoms, where it is closely packed by allowing animals to run over it, is practiced to a considerable extent both in this country and in Europe, and, as recent experiments at the Pennsylvania Station indicate, it is probably as safe a method as storing in an open shed where no special precautions are taken to keep the manure moist throughout. The objections to it are that the manure is subjected to extremes of drought and moisture and must suffer injury in consequence unless special precautions are taken to guard against these extremes.

A third method known as the "deep-stall" method, which originated in Europe and is practiced to some extent in this country, is that in which the soil in the stable is removed to a level below that of the outside and the bottoms are tamped or cemented. The manure is allowed to accumulate under the animals until it is hauled to the fields, bedding being used in abundance. The feeding troughs are made adjustable so that they can be raised or lowered as required. The manure becomes highly compacted and is kept in a favorable condition of moisture, so that fermentation proceeds slowly and uniformly. At the same time the manure is completely protected from the action of the weather,

and, as experiments at the Ohio and Pennsylvania stations show, there is little or no loss of fertilizing constituents. The experiments of the Pennsylvania Station show, however, "that ammonia is lost very rapidly by such manure, if it be allowed to lie after the removal of the stock, without such covering as will retain the moisture and exclude the air."

Whatever the system adopted, the following general rules should be observed in the storage of manure: (1) Spread the manure out uniformly; (2) guard as much as possible against the access of air; (3) keep the manure always moist, but not too wet; (4) protect the heap from extremes of heat as of moisture.

USE OF MANURE.

It is the prevailing opinion of chemists as well as practical men that where it is practicable it is best to apply manure and urine to the soil in the freshest possible condition. The fertilizing constituents of well-rotted manure, as already explained, are more quickly available to plants, and the manure itself is less bulky and easier to distribute. On the other hand, fresh manure mixed with the soil readily undergoes a fermentation which not only increases the availability of its own fertilizing constituents, but also assists in rendering soluble the hitherto insoluble fertilizing constituents of the soil. In fact, even with special precautions to prevent injurious fermentation under the feet of the animals and in the heap, the greatest return is likely to be gotten from manure applied in the fresh condition.

The form in which manure should be applied (whether fresh or rotted) is determined largely by the soil on which it is to be used. If improvement of the mechanical condition is the main object sought, the best results will be obtained by applying the fresh manure to the heavy clay soils and the well-rotted manure to the light soils. If, however, the prompt action of the fertilizing constituents of the manure is desired, light soils, in a favorable season, are likely to utilize coarse manure to better advantage than heavy soils. Decomposition takes place slowly in heavy soils and the constituents of the fresh manure become available very slowly. In light soils, on the other hand, unless the season is dry, the conditions are such that the manure decomposes readily, and the fertilizing constituents are probably rendered available as fast as the plant needs them. There is also considerable danger on this class of soils that some of the soluble constituents will be carried away in the drainage if well-rotted manure is applied. For this reason such manure should be applied to light soils shortly before it is likely to be needed by the crop. In general, it may be said that for spring application the more readily available rotted manure is preferable to the fresh unrotted material.

On clay soils it often happens that manure produces no effect whatever during the first year on account of slowness of decomposition,

but since the clay possesses very powerful absorptive properties the manure is not lost. The fertilizing constituents are retained in the soil and are finally utilized by the crop. There is therefore little or no danger on this account in applying manure to clay soils a long while in advance of the planting of the crop. During dry seasons the manure may produce little effect, but with a sufficient amount of moisture its action is likely to be considerable. The application to such soils of large quantities of manure improves their physical condition.

The behavior of calcareous soils toward manure is very variable, depending upon the compactness of the soil. In those which are sufficiently porous decomposition goes on with great rapidity, and the soluble fertilizing constituents formed may be partially carried away in the drainage water before they can be taken up by the plants. For this reason, as in case of light soils, the manure should be applied shortly before it is needed by the crop.

Many experiments, notably those made by the Michigan and Wisconsin stations in this country, have shown that barnyard manure is one of the most effective means of increasing the productiveness of swamp or muck soils. This is thought to be due largely to the increase of available nitrogen brought about by the application of the manure.

The climate also may have an important bearing on this subject. In a warm, damp climate it is a matter of comparative indifference whether the manure is fresh or well rotted when it is applied, since under these conditions decomposition in the soil will be sufficiently rapid. In a dry season, however, it is well known that excessive applications of undecomposed manure manifest a tendency to "burn out" the soil, and this tendency, as has just been stated, is more marked in light soils than in heavy. In cold climates, where the season is short and the conditions for rapid fermentation in the soil unfavorable, the use of fermented manure is preferable.

Fresh manure has a forcing effect and tends to produce stems and leaves at the expense of fruit and grain. It is therefore better for early garden truck, grasses, and forage plants than for cereals or fruits.

Direct application of fermenting manure, as is well known, seriously injures the quality of tobacco, sugar beets, and potatoes, although mangel-wurzels appear to profit by large applications. For these reasons it is advisable in the case of cereals, tobacco, potatoes, and sugar beets to use only well-rotted manure or to apply the manure to the previous crop, or, where land is to be planted in the spring, to apply in the fall and allow to decompose during the winter. Sir J. B. Lawes has pointed out, however, that wheat on light soil is benefited by direct applications of manure, and that it is only on heavy soils that it is best to apply it to the preceding crop.

"Manifestly," as Storer remarks, "the rankness of fresh dung and

urine could be controlled and utilized by applying the manure in small quantities and supplementing it with artificial fertilizers of kinds appropriate to the crops that are to be grown."

What has been said above regarding the application of fresh manure applies especially to manure containing only small amounts of coarse undecomposed litter. It is not generally advisable to apply very coarse manure before the litter has become at least partially decomposed.

It appears, therefore, that no fixed rules regarding the condition in which manure should be used which will apply to all cases can be laid down. It is a matter which naturally must be left largely to the individual judgment of the farmer, based upon a careful study of the character of the soil and climate and the requirements of the crop to be grown.

METHODS OF APPLYING MANURE.

In applying manure to the field three methods are pursued: (1) The manure is placed in larger or smaller heaps over the field and allowed to remain some time before being spread; (2) it is broadcasted and allowed to lie on the surface for some time, or plowed in immediately, and (3) it is applied in the hill or drill with the seed.

The first method is objectionable because it increases labor of handling and chances of loss by fermentation and leaching, while uniform distribution of the manure is not secured. The spots on which the heaps stand are strongly manured with the leachings of the manure, while the rest of the field receives the coarse parts of the manure largely deprived of its valuable constituents. Another disadvantage of this method is that proper fermentation is interfered with by the leaching out of the nitrogenous matter and the drying action of the wind. The practice of storing manure in large heaps in the field is subject to some extent to the same objections. If, however, the heap is not allowed to lie too long and is carefully covered with earth the loss may be greatly reduced.

Spreading the manure and allowing it to lie on the surface should be practiced only on level fields where there is no danger from surface washing. It has been claimed that when manure is spread broadcast and allowed to lie on the surface there may be a serious loss of ammonia into the air, but experiments have shown that, in case of properly prepared manure, loss from this cause must be very small. On a leachy soil there may be a loss of soluble constituents in the drainage if the manure is spread a long while before the crop is planted, but in ordinary practice the loss from this source is also likely to be insignificant. In this method of application the fertilizing constituents of the manure are uniformly distributed, the liquid portion being gradually and thoroughly incorporated with the soil particles. One serious disadvantage,

however, of the method is that the manure before being plowed in is leached to a large extent of its soluble nitrogenous compounds, which, as we have already observed, are necessary for fermentation, and therefore it does not so readily ferment in the soil. It is not advisable, therefore, in the case of light or sandy soils, to follow this practice, but it is preferable to plow the manure in as soon as spread.

As to the depth to which it is advisable to plow the manure in, the general rule should be observed that it should not be so deep as to prevent the access of sufficient moisture and air to insure fermentation and nitrification and to permit of rapid washing down of nitrates to the drain. In very compact soils the depth should not exceed 4 inches. In light soils this depth may be considerably increased, although in such soils there is more danger of loss by drainage than with heavy clay soils.

Application in the hill or drill is useful where the supply of manure is limited and the full immediate effect is desired. For forcing truck crops this method is especially valuable. Well-rotted manure is best suited to this method of application. It has been claimed, however, that manure applied in this way sometimes injures the appearance of root crops, especially potatoes, by increasing the amount of scab.

The so-called parking system, or feeding animals on the land, is a method of application which has many advantages; but the distribution of the manure by this system is irregular and subject to the same objection as broadcasting.

The application of liquid manure has certain obvious advantages and is largely practiced, especially in Europe. Manure leachings is a quick-acting, forcing manure, and is especially valuable for grass. The expense of cisterns for collecting the leachings and the trouble of hauling and distributing, together with the care which must be exercised to prevent loss of nitrogen from the readily fermentable liquid when it stands for any length of time, render it doubtful, however, whether this method is practicable except for special purposes and under peculiar conditions.

RATE OF APPLICATION.

As to the rate at which manure should be applied no fixed rules can be given. The rate will depend upon the character of the soil, the quality of the manure, the nature of the crop, and the frequency of application. Thaer, a German writer, states 17 to 18 tons per acre to be an abundant application, 14 tons good, and 8 to 9 light; other German writers consider 7 to 10 tons light, 12 to 18 tons usual, 20 tons or more heavy, and 30 tons very heavy. Stephens suggests 8 to 12 tons for roots and 15 to 20 tons supplemented by commercial fertilizers for potatoes. Sir Henry Gilbert considers 14 tons per acre annually excessive for wheat and barley. Twenty tons is a frequent application

in New Jersey, as well as in other regions where truck farming is practiced, and still larger amounts are often used. As a general rule it is more scientific to apply small amounts of manure frequently than to apply large amounts at longer intervals, except when the purpose is to warm the soil to force early crops.

COMBINING BARNYARD MANURE WITH OTHER FERTILIZING MATERIALS.

It has been the general experience that probably the best way to utilize barnyard manure is in combination with such materials as supplement and conserve its fertilizing constituents. It has already been pointed out that certain substances, such as kainit and superphosphate, which are sometimes employed as preservatives, may also be used to advantage to improve the fertilizing value of the manure, but it is necessary to do more than this if a well-balanced fertilizer is desired, for, as has been shown, barnyard manure considered simply as a supplier of nitrogen, phosphoric acid, and potash is comparatively poor. The proportions of potash and phosphoric acid especially are low. The potash, however, is in a very available form and does not need to be reenforced to the same extent as the much less available phosphoric acid.

Although nitrogen is one of the most abundant constituents in manure, it has been found that in order to get the best results in general it should be reenforced if prompt action is desired. This is explained by the fact that a large part of the nitrogen of manure is very slowly available. Sir Henry Gilbert says on this point:

> The nitrogen of farmyard manure must obviously exist in very different conditions. That due to the urine of animals will be most rapidly available, that in the finely divided matter in the feces will be much more slowly available, and that in the litter still more slowly available. Hence, the small proportion that is at once effective and the very large amount that accumulates within the soil in a very slowly available condition.

Experiments at Rothamsted, as well as at the New Jersey Station (see p. 12), indicate that the nitrogen of barnyard manure is much less available, weight for weight, than that of sulphate of ammonia, the availability varying widely, however, with the character and treatment of the manure.

What has been said about supplementing barnyard manure with more concentrated fertilizing materials should not be taken to imply that the two kinds of fertilizers should necessarily be composted or applied at the same time. In fact, as already pointed out, nitrates should never be composted with manure on account of the danger of loss of nitrogen through denitrification. It may be desirable to apply the manure at intervals of several years, while the concentrated fertilizers would need to be applied annually. However this may be, the

facts above given should be borne in mind in applying the supplementary fertilizers.

Whether the farmer can afford to incur the necessary labor and expense involved in the preparation of composts is a question on which there is considerable difference of opinion. This is a matter which must be determined largely by individual needs and conditions, but undoubtedly the manure heap may be utilized to advantage for such purposes as reducing bones and other waste products of the farm and for "killing" cotton seed before it is applied to the soil.

The fermenting of peat with stable manure was formerly practiced to a considerable extent. Where such a compost is desired the materials should be laid down in alternate layers in the proportion of about five parts of peat to one of manure.

LASTING OR CUMULATIVE EFFECT OF BARNYARD MANURE.

Barnyard manure is one of the most efficient means at the disposal of the farmer to permanently improve his soil. Probably no other fertilizer possesses to so great a degree the power of restoring worn soils to productiveness and giving them lasting fertility. It accomplishes this result, however, not so much by the actual fertilizing constituents which it supplies as by improving the physical properties of the soil, increasing the amount of humus, which is generally deficient in worn soils, improving its texture, and increasing its water-absorbing and water-holding power. Experiments have shown that the influence of manure may be perceptible twenty years after application. Observations at Rothamsted, England, during forty years on barley unmanured, manured continuously, and manured during the first twenty years only showed that "there was gradual exhaustion and reduction of produce without manure, and gradual accumulation and increase of produce with the annual application of farmyard manure. But when the application was stopped, although the effect of the residue from the previous applications was very marked, it somewhat rapidly diminished, notwithstanding that calculation showed an enormous accumulation of nitrogen as well as other constituents."

The yield, however, was maintained for twenty years considerably higher than that on the unmanured soil. Continuous manuring of wheat at the rate of 14 tons per acre annually for forty years resulted in an average increase of yield from year to year of one-fourth bushel per acre, or a total of about 10 bushels in forty years. While it is true that there is a constant increase in the productiveness of soil on which barnyard manure is applied regularly, it is not as great as the amounts applied would seem to justify. This is chiefly due to the fact, already explained, that the nitrogen accumulates in the soil in slowly available forms.

SUMMARY.

(1) Barnyard manure is the most important manurial resource of the farm and should be carefully saved and used. It represents fertility which is drawn from the soil and must be returned to it if productiveness is to be maintained. It not only enriches the soil with the nitrogen, phosphoric acid, and potash, but it also renders the stored-up materials of the soil more available, improves the mechanical condition of the soil, makes it warmer, and enables it to retain more moisture.

(2) On the basis of prices charged for commercial fertilizers it is estimated that the average value of the manure annually produced by each horse or mule is $27, by each head of cattle $19, by each hog $12, and by each sheep $2. Probably less than half these values are actually realized in practice.

(3) The urine is by far the most valuable part of the excreta of animals. It is especially rich in readily available nitrogen, which rapidly escapes into the air if special precautions are not taken to prevent its loss. It is also rich in potash, but deficient in phosphoric acid. It should, as a rule, be used in connection with the solid dung, the one thus supplying the deficiencies of the other and making a more evenly balanced manure.

(4) Barnyard manure is a very variable substance, its composition and value depending mainly upon (1) age and kind of animal, (2) quantity and quality of food, (3) proportion of litter, and (4) method of management and age. Ordinary barnyard manure properly cared for may be assumed to contain on the average one-half per cent each of nitrogen and potash and one-third per cent of phosphoric acid.

(5) Mature animals, neither gaining nor losing weight, excrete practically all the fertilizing constituents consumed in the food. Growing animals may excrete as little as 50 per cent of the fertilizing constituents of the food, milch cows excrete from 65 to 85 per cent, fattening or working animals from 85 to 95 per cent. As regards the fertilizing value of equal weights of manure in its normal condition, farm animals probably stand in the following order: Poultry, sheep, pigs, horses, cows.

(6) The amounts of fertilizing constituents in the manure stand in direct relation to those in the food. As regards the value of manure produced, the concentrated feeding stuffs, such as meat scrap, cotton-seed meal, linseed meal, and wheat bran, stand first, the leguminous plants (clover, peas, etc.) second, the grasses third, cereals (oats, corn, etc.) fourth, and root crops, such as turnips, beets, and mangel-wurzels, last.

The nitrogen of tne food exerts a greater influence on the quality of the manure than any other constituent. It is the most costly fertilizing constituent. It undergoes more modification in the animal stomach than the mineral constituents (potash and phosphoric acid), and rapidly escapes from the manure in fermentation. The secretion of urine

increases with the increase of nitrogenous substances in the food, thus necessitating the use of larger amounts of litter and affecting both the amount and value of the manure. The use of watery foods, as is obvious, produces the same result.

(7) Barnyard manure rapidly undergoes change. When practicable to remove the manure and spread it on the field at short intervals the losses of valuable constituents need not be very great, but when the manure must be stored for some time the difficulties of preservation are greatly increased.

(8) The deterioration of manure results from two chief causes, (*a*) fermentation, whereby nitrogen, either as ammonia or in the gaseous state, is set free, and (*b*) weathering or leaching, which involves a loss of the soluble fertilizing constituents. The loss from destructive fermentation may be largely prevented by the use of proper absorbents and by keeping the manure moist and compact. Loss from leaching may be prevented by storage under cover or in water-tight pits. Extremes of moisture and temperature are to be avoided, and uniform and moderate fermentation is the object to be sought. To this end it is advisable to mix the manure from the different animals thoroughly in the heap.

(9) The disposition to be made of the manure of the farm (both fermented and unfermented) must be determined largely by the nature of the crop and soil. Where improvement of the mechanical condition of the soil is the principal object sought, fresh manure is best adapted for this purpose to heavy soils and well-rotted manure to light soils. Where prompt action of the fertilizing constituents is desired, the best results will probably be obtained by applying fresh manure to the light soils, although excessive applications in this case should be avoided on account of the danger of "burning out" of the soil in dry seasons. Fresh manure has a forcing effect, and is better suited to early garden truck, grasses, and forage plants than to plants grown for seed, such as cereals, or to fruits. Direct applications to root crops, such as sugar beets and potatoes, or to tobacco, often prove injurious. The manure should be spread when carried to the field, and not left in heaps to leach.

The rate of application must be determined by individual circumstances. As a rule it is better to manure lightly and frequently than to apply a large amount at longer intervals.

(10) One of the best ways to utilize barnyard manure is to apply it in connection with such fertilizing materials as supplement its fertilizing constituents. These materials may be either composted with the manure or used separately, except in case of a nitrate, such as nitrate of soda, which should never be composted with barnyard manure on account of danger of denitrification and loss of nitrogen. As is well known, barnyard manure is lasting in its effects, and in many cases need not be applied so frequently as the more soluble and quick-acting superphosphates and potash and nitrogen salts.

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